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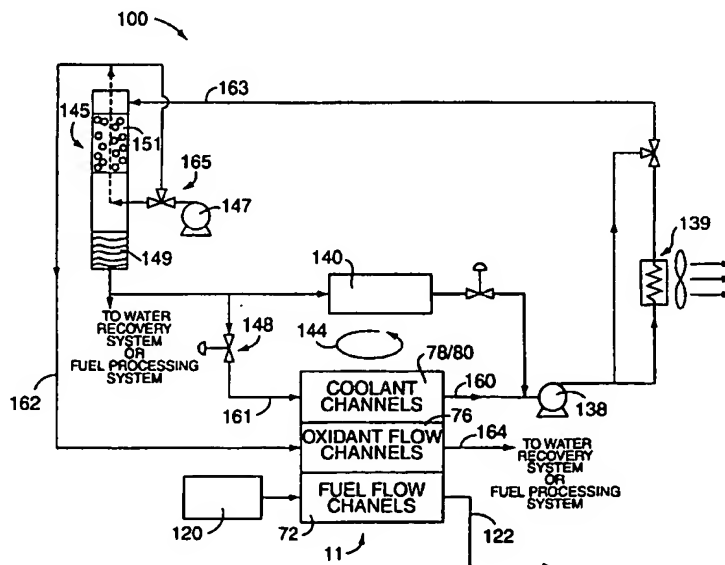
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(54) Title: COOLANT TREATMENT SYSTEM FOR A DIRECT ANTIFREEZE COOLED FUEL CELL ASSEMBLY



(57) Abstract: A coolant treatment system (100) for a direct antifreeze cooled fuel cell power plant including a degassifier (145) for providing interaction between an oxidant and an antifreeze solution which has circulated throughout the fuel cell power plant so that dissolved gases within the antifreeze solution are removed. The fuel cell power plant is configured to allow the antifreeze solution to be in direct fluid communication with the fuel cell assemblies (11) comprising the fuel cell power plant.

**COOLANT TREATMENT SYSTEM FOR A DIRECT ANTIFREEZE COOLED
FUEL CELL ASSEMBLY**

FIELD OF THE INVENTION

5 This invention relates in general to a coolant treatment system for a fuel cell assembly, and deals more particularly with a coolant treatment system for a fuel cell assembly which is in direct communication with an antifreeze coolant solution.

BACKGROUND OF THE INVENTION

10 Electrochemical fuel cell assemblies are known for their ability to produce electricity and a subsequent reaction product through the interaction of a fuel being provided to an anode and an oxidant being provided to a cathode, thereby generating an external current flow between these substrates. Such fuel cell assemblies are very useful and sought after due to
15 their high efficiency, as compared to internal combustion fuel systems and the like. Fuel cell assemblies are additionally advantageous due to the environmentally friendly chemical reaction by-products that are produced, such as water. In order to control the temperature within the fuel cell assembly, a water coolant is typically provided to circulate about the fuel cell
20 assembly. The use of reformed fuels within fuel cell assemblies makes them particularly sensitive to possible water contaminants.

 Electrochemical fuel cell assemblies typically employ hydrogen as the fuel and oxygen as an oxidant where the reaction by-product is water. Such
fuel cell assemblies may employ a membrane consisting of a solid polymer
25 electrolyte, or ion exchange membrane, disposed between the two substrates formed of porous, electrically conductive sheet material - typically, carbon fiber paper. The ion exchange membrane is also known as a proton exchange membrane (hereinafter PEM), such as sold by DuPont under the trade name NAFION™. Catalyst layers are formed between the membrane
30 and the substrates to promote the desired electrochemical reaction. The

combination of the PEM, the two catalyst layers and the substrates are referred to as a membrane electrode assembly.

In operation, hydrogen fuel permeates the porous substrate material of the anode and reacts with the catalyst layer to form hydrogen ions and electrons. The hydrogen ions migrate through the membrane to the cathode and the electrons flow through an external circuit to the cathode. At the cathode, the oxygen-containing gas supply also permeates through the porous substrate material and reacts with the hydrogen ions and the electrons from the anode at the catalyst layer to form the by-product water. Not only does the ion exchange membrane facilitate the migration of these hydrogen ions from the anode to the cathode, but the ion exchange membrane also acts to isolate the hydrogen fuel from the oxygen-containing gas oxidant. The reactions taking place at the anode and cathode catalyst layers are represented by the equations:

Anode reaction: $\text{H}_2 \rightarrow 2\text{H}^+ + 2\text{e}$

Cathode reaction: $\frac{1}{2} \text{O}_2 + 2\text{H}^+ + 2\text{e} \rightarrow \text{H}_2\text{O}$

Conventional PEM fuels cells have the ion exchange membrane positioned between two gas-permeable, electrically conductive plates, referred to as the anode and cathode plates. The plates are typically formed from graphite, a graphite-polymer composite, or the like. The plates act as a structural support for the two porous, electrically conductive substrates, as well as serving as current collectors and providing the means for carrying the fuel and oxidant to the anode and cathode, respectively. They are also utilized for carrying away the reactant by-product water during operation of the fuel cell.

When flow channels are formed within these plates for the purposes of feeding either fuel or oxidant to the anode and cathode plates, they are referred to as "fluid flow field plates". These plates may also function as water transfer plates in certain fuel cell configurations. When these plates simply overlay channels formed in the anode and cathode porous material,

they are referred to as "separator plates". Moreover, the plates may have formed therein reactant feed manifolds which are utilized for supplying fuel to the anode flow channels or, alternatively, oxidant to the cathode flow channels. They also have corresponding exhaust manifolds to direct unreacted components of the fuel and oxidant streams, and any water generated as a by-product, from the fuel cell. Alternatively, the manifolds may be external to the fuel cell itself, as shown in commonly owned U.S. Patent No. 3,994,748, issued to Kunz et al.

The catalyst layer in a fuel cell assembly is typically a carbon supported platinum or platinum alloy, although other noble metals or noble metal alloys may be utilized. Multiple electrically connected fuel cells consisting of two or more anode plate/membrane electrode assembly/cathode plate combinations are referred to as a "fuel cell stack". A fuel cell stack is typically electrically connected in series.

Recent efforts at producing the fuel for fuel cell assemblies have focused on utilizing a hydrogen rich gas produced from the chemical conversion of hydrocarbon fuels, such as methane, natural gas, gasoline or the like, into hydrogen. This process requires that the hydrogen produced must be efficiently converted to be as pure as possible, thereby ensuring that a minimal amount of carbon monoxide and other undesirable chemical byproducts are produced. This conversion of hydrocarbons is generally accomplished through the use of a steam reformer or an autothermal reformer. Reformed hydrocarbon fuels frequently contain quantities of ammonia, NH_3 , as well as significant quantities of carbon dioxide, CO_2 .

These gases tend to dissolve and dissociate into the water which is provided to, and created within, the fuel cell assembly. The resultant contaminated water supply may cause the conductivity of the water to increase to a point where shunt current corrosion occurs in the coolant channels and manifold leading to degradation of fuel cell materials, as well as reducing the conductivity of the PEM and thereby reducing the efficiency of the fuel cell assembly as a whole.

As disclosed above, the anode and cathode plates provide coolant channels for the circulation of a water coolant, as well as for the wicking and

carrying away of excessive water produced as a by-product of the fuel cell assembly operation. The water so-collected and circulated through a fuel cell assembly is susceptible to water contamination and may therefore damage and impair the operation of the fuel cell assembly as the contaminated water
5 circulates throughout the fuel cell assembly.

It is therefore necessary to provide a system which may protect the fuel cell assembly from water contamination, such as is described in commonly owned U.S. Patent No. 4,344,850, issued to Grasso. Grasso's system for treating the coolant supply of a fuel cell assembly, as illustrated in
10 Fig. 1 of 4,344,850, utilizes a filter and demineralizer for purifying a portion of the coolant supplied to the fuel cell assembly. A deaerator is also utilized to process the condensed water obtained from a humidified cathode exit stream. As discussed in Grasso, the heat exchange occurring between the coolant stream and the body of the fuel cell assembly is accomplished according to
15 commonly assigned U.S. Patent No. 4,233,369, issued to Breault et al.

It is important to note that Grasso's coolant system does not provide for the cleansing of the coolant stream as a whole. This is due to the fact that the coolant conduits in Grasso, being fashioned from copper or the like, are not in diffusable communication with the body of the fuel cell assembly and
20 as such, the coolant stream does not receive contamination from, inter alia, the CO₂ or NH₃ present in the reformed fuel stream. The burden of cleansing the coolant stream in Grasso is therefore born solely by the filter and demineralizer and results in greater wear on these components and hence greater repairs and replacements. Grasso also utilizes two distinct coolant
25 pumps for circulating the coolant.

Another coolant treatment system has been disclosed in commonly assigned co-pending U.S. Patent Application, Serial No. 09/295,732, entitled "Water Treatment System for a Fuel Cell Assembly". U.S. Patent Application, Serial No. 09/295,732, utilizes an unique arrangement of demineralizers and
30 degasifiers to cleanse the entire circulating coolant stream while providing for the humidification of an inputted oxidant stream.

In addition to water treatment concerns, the operation of a typical PEM fuel cell may also be adversely affected by extremes in environmental

conditions, such as when the operating environment of the PEM fuel cell falls below the freezing point of water. In such circumstances, the volumetric expansion of the water coolant may cause severe damage to the PEM fuel cell. Commonly assigned co-pending U.S. Patent Application, Serial No. 5 09/322,733, entitled "Method and Apparatus for Thermal Management of a Fuel Cell Assembly", addresses this additional concern.

U.S. Patent Application, Serial No. 09/322,733, provides a fuel cell assembly with a cooler plate having channels formed therein for carrying an antifreeze solution, such as a glycol solution or the like, for maintaining the 10 fuel cell assembly above freezing, and alternatively, for quickly raising the fuel cell assembly above freezing during times of cold start-ups. The cooler plate is sealed from communication with the substrate of the fuel cell assembly to protect against contamination of the substrate and catalyst materials and subsequent failing of the fuel cell assembly as a whole. The addition of a 15 cooler plate in a fuel cell assembly creates an associated increase in the weight and volume of the fuel cell assembly which is only exacerbated when a plurality of planar fuel cell assemblies are joined together to form a fuel cell stack. This increase in both weight and volume is especially troublesome and undesirable in applications involving fuel cell powered vehicles and the like.

20 Accordingly, commonly assigned co-pending U.S. Patent Application, Serial No. 09/359,475, entitled "Direct Antifreeze Cooled Fuel Cell", discloses a coolant system for use with a fuel cell assembly whereby an antifreeze solution is in fluid communication with the fuel cell assembly, but is kept from contaminating the electrolyte and catalyst through a judicious balance of 25 pressures within the fuel cell assembly and the wetproofing of certain constituent elements of the fuel cell assembly.

With the forgoing problems and concerns in mind, it is the general object of the present invention to provide a fuel cell assembly with a coolant treatment system which overcomes the above-described drawbacks. 30 Accordingly, an integrated coolant treatment system is proposed having an antifreeze cooling solution which is not isolated from the components of the fuel cell assembly, and which also minimizes the accumulation of pure water within the fuel cell assembly.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a coolant treatment system for a fuel cell assembly.

It is another object of the present invention to provide a coolant
5 treatment system which also humidifies the oxidant flows to the cathode of a fuel cell assembly.

It is another object of the present invention to protect a fuel cell assembly from the debilitating effects of freezing temperatures.

According to one embodiment of the present invention, a coolant
10 treatment system for a fuel cell power plant has a plurality of electrochemical fuel cell assemblies in electrical connection with each other, the fuel cell assemblies each having an electrolyte, an anode, a cathode. The anode and the cathode are each adapted to support anode and cathode water transport
15 plates through which a fuel and an oxidant are fed to the anode and the cathode, respectively. In addition, one of the anode and the cathode water transport plates is adapted to support a coolant channel through which an antifreeze solution is circulated. The antifreeze solution is in fluid communication with one of said anode and cathode water transport plates.

An oxidant source is utilized to provide the fuel cell power plant with
20 the oxidant, while a coolant conduit exhausts the antifreeze solution from the fuel cell power plant.

In operation, a degasifying apparatus treats the antifreeze solution from the coolant conduit together with the oxidant from the oxidant source by removing contaminants from the antifreeze solution and by humidifying the
25 oxidant. The degasifying apparatus subsequently provides the fuel cell power plant with the humidified oxidant.

These and other objectives of the present invention, and their preferred embodiments, shall become clear by consideration of the specification, claims and drawings taken as a whole.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 illustrates a section taken through a PEM fuel assembly incorporating an antifreeze coolant solution in direct fluid communication with the fuel cell assembly.

5 Fig. 2 is a simplified schematic illustration of a coolant treatment system incorporating a direct antifreeze cooled fuel cell assembly according to one embodiment of the present invention.

Fig. 3 is a simplified schematic illustration of a coolant treatment system incorporating a direct antifreeze cooled fuel cell assembly according to another embodiment of the present invention.

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DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Fig. 1 illustrates a partial cross-sectional view of a fuel cell assembly 11 which, as a component of an overall coolant treatment system (to be described later), is capable of being in direct fluid communication with an antifreeze coolant solution without suffering the detrimental effects of such a solution. The fuel cell assembly 11 typically produces only approximately 0.6-0.7 V, therefore, in order to produce a desired power supply, it is necessary for a great many fuel cells to be electrically joined together. The fuel cell assembly 11 of Fig. 1 employs an electrolyte 52 such as a proton exchange membrane ("PEM"), an anode catalyst 54 and a cathode catalyst 56 secured on opposing sides of the electrolyte 52. The fuel cell assembly 11 also includes a wet-proofed anode support means 50 that is secured in direct fluid communication with the anode catalyst 54 between an anode water transport plate 60 and the anode catalyst 54 for feeding the reactant fuel stream adjacent to the anode catalyst 54. The wet-proofed anode support means 50 may include one or more porous layers, such as a porous anode substrate 58, a porous anode diffusion layer 66, or both the porous anode substrate 58 and porous anode diffusion layer 66 secured adjacent each other between the anode water transport plate 60 and anode catalyst 54, wherein at least one of the porous layers, 58 and 66 respectively, is wetproofed.

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As utilized in the present application, 'wetproofed', is a term of art whereby a constituent element of the fuel cell assembly **11** is immersed in a water repellant emulsion, such as Teflon® or the like, and subsequently heated in a manner known to those in the art, thereby making the element so
5 treated substantially hydrophobic.

The fuel cell assembly **11** also includes a wetproofed cathode support means **55** that is secured in direct fluid communication with the cathode catalyst **56** between a cathode water transport plate **64** and the cathode catalyst **56** for feeding a reactant oxidant stream adjacent to the cathode
10 catalyst **56**. The wetproofed cathode support means **55** may include one or more porous layers, such as a porous cathode substrate **62**, a porous cathode diffusion layer **68**, or both the porous cathode substrate **62** and porous cathode diffusion layer **68** secured adjacent each other between the cathode water transport plate **64** and cathode catalyst **56**, wherein at least
15 one of the porous layers, **68** and **62** respectively, is wetproofed. The porous cathode substrate **62** and porous anode substrate **58** may be porous carbon-carbon fibrous composites having a porosity of about 65% to about 75%, and may be wet-proofed by a hydrophobic substance such as Teflon®, as discussed previously.

20 The porous cathode water transport plate **64** is in direct fluid communication with the porous cathode substrate **62**, the porous cathode diffusion layer **68** and the cathode catalyst **56**. Similarly, the porous anode water transport plate **60** is in direct fluid communication with the porous anode substrate **58**, the porous anode diffusion layer **66** and the anode
25 catalyst **54**.

Fig. 1 further illustrates an anode flow field which may comprise of an unillustrated fuel inlet and a plurality of fuel flow channels **72** defined within the anode water transport plate **60**. Similarly, a cathode flow field may consist of an unillustrated oxidant inlet and a plurality of oxidant flow channels
30 **76** defined within the cathode water transport plate **64**. The anode flow field and cathode flow field may also consist of cavities, differing channels or grooves well known in the art and defined within fuel cell components to direct

the fuel and process oxidant streams to pass in contact with the anode and cathode catalysts, **54** and **56** respectively. The porous anode and cathode water transport plates, **60** and **64**, may be structured to cooperate with adjacent water transport plates (not shown) so that anode side coolant channels **78A**, **78B** and **78C** defined within the anode water transport plate **60**, and cathode side coolant channels **80A**, **80B**, and **80C** defined within the cathode water transport plate **64**, may cooperate in mirror-image association with coolant channels of the adjacent water transport plates of adjacent fuel cell assemblies (not shown), thereby forming a fuel cell stack including a network of coolant channels for delivering a coolant fluid stream to the water transport plates, **60** and **64** respectively.

The coolant fluid stream of the present invention is comprised of an antifreeze solution which, as discussed above, is in direct fluid communication with the constituent elements of the fuel cell assembly **11**. The direct antifreeze solution may be any organic antifreeze solution that does not wet the wetproofed cathode substrate and that is essentially non-volatile at cell operating temperatures. For purposes of the present application, 'non-volatile' is defined to mean that the antifreeze solution sustains a loss of less than 10% of its antifreeze volume for every 500 operating hours of the fuel cell assembly at standard operating temperatures.

Alternatively, a first preferred direct antifreeze solution may be a special direct antifreeze solution having the following characteristics: 1. a freezing point of at least -29°C (-20°F); 2. a surface tension greater than 60 dynes per centimeter (hereafter "dyne/cm") at about 65°C (150°F); 3. a partial pressure of antifreeze above the solution at about 65°C (150°F) that is less than 0.005 mm of mercury (hereafter "mm Hg"); and, 4. that is capable of being oxidized by catalysts of the fuel cell at fuel cell voltages. A second preferred antifreeze solution may be an alkanetriol direct antifreeze solution, and, in particular, an alkanetriol selected from the group consisting of glycerol, butanetriol, and pentanetriol. The alkanetriol direct antifreeze may be an antifreeze solution containing any alkanetriol.

In operation of the fuel cell assembly 11, the anode side coolant channels 78A, 78B, 78C and cathode side coolant channels 80A, 80B, 80C are in fluid communication with the coolant feed conduit and coolant discharge conduit (described later), so that an antifreeze coolant stream from the coolant feed conduit passes through the anode and cathode coolant channels, and into the anode and cathode water transport plates, 60 and 64, to saturate the pore volume of the water transport plates, 60 and 64. The antifreeze coolant then passes into the coolant discharge conduit. By filling the open pore volume of the anode and cathode water transport plates, 60 and 64, the antifreeze solution stream forms a gas barrier or seal preventing the gaseous reactant fuel in the reactant fuel channels 72 from flowing into oxidant channels in an adjacent cell. By wetproofing the porous anode substrate 58 layer and/or the porous anode diffusion layer 66, the liquid antifreeze solution is restricted from moving out of the anode water transport plate 60 and passing through the anode substrate and diffusion layers, 58 and 66, into contact with the anode catalyst 54.

Similarly, by wetproofing the porous cathode substrate layer 62 and/or the cathode diffusion layer 68, the liquid antifreeze coolant stream is prevented from moving out of the cathode water transport plate 64 and passing through the cathode substrate 62 and cathode diffusion layer 68 and into contact with the cathode catalyst 56. Additionally, as the fuel cell assembly 11 operates, a quantity of by-product water is continually formed at the cathode catalyst 56 and is removed as water vapor or liquid into the reactant oxidant stream flowing through the cathode flow field or oxidant channels 76 defined within the cathode water transport plate 64. Moreover, a portion of the by-product water is removed from the fuel cell assembly 11 with the antifreeze coolant stream through the coolant discharge conduit (to be described in more detail later).

The pressure of the antifreeze solution is controlled to be lower than the pressure at which the reactant fuel and oxidant are circulated throughout the fuel cell assembly 11. Therefore, the migration of the by-product water occurs substantially in a direction from the cathode catalyst 56 towards the

cathode water transport plate **64**, effectively inhibiting the migration of the antifreeze solution in the opposite – and undesirable – direction.

It can therefore be seen that by a judicious balance of reactant and coolant pressures, and by wetproofing certain elements within the fuel cell assembly **11**, it is possible to utilize a directly fed antifreeze solution in the fuel cell assembly **11** without danger to either the electrolyte **52** or the anode and cathode catalysts, **54** and **56** respectively. As discussed previously, by not requiring that the antifreeze solution be carried within sealed cooler plates, the present invention advantageously allows for fuel cell stacks to be constructed having lower weight and volume parameters than previously possible.

The inputted reactant fuel and oxidant may be fed through the fuel cell assembly **11** utilizing axial feed manifolding, exterior manifolding or a combination of the two - the specific arrangement of manifolding being commonly known to those skilled in the art and not of primary concern with respect to the present invention. As depicted in Fig. 1, the oxidant channels **76** are typically oriented orthogonal to the fuel channels **72**, but may alternatively be oriented in any manner provided that the fuel cell assembly **11** is adequately supplied with the proper amount of these reactants, without departing from the broader aspects of the present invention.

An exemplary fuel cell including a PEM electrolyte, wetproofed anode and cathode substrates, **58** and **62**, and anode and cathode diffusion layers, **66** and **68**, demonstrated efficient test performance without unacceptable adsorption of a glycerol-water antifreeze solution to the anode or cathode catalysts, **54** and **56** respectively. The exemplary fuel cell included a 15 micron PEM electrolyte within a membrane electrode assembly acquired from W.L. Gore and Associates, Inc. of Elkton, MD as product identification no. "PRIMEA – 5560". The anode catalyst consisted of a platinum - ruthenium alloy. The cathode catalyst was platinum.

The porous anode and cathode substrate layers were porous carbon - carbon fibrous composite having a thickness of approximately 0.006 – 0.007 inches, and a porosity of about 65% - 75%, and were acquired as grade

TGP-H-060 from the Toray Company of New York, NY. The anode and cathode substrate layers were uniformly wetproofed with Teflon grade "FEP – 121" sold by the E. I. DuPont Company, of Wilmington, Delaware, by wet-proofing procedures well-known in the art.

5 The porous anode and cathode gas diffusion layers were applied to both the anode and cathode substrates by procedures well-known in the art and described in U.S. Patent 4,233,181, which patent is owned by the assignee of all rights in the present invention. The anode and cathode diffusion layers were approximately 0.076 – 0.102 mm (0.003 – 0.004
10 inches) thick, and were comprised of about 50 percent Vulcan XC-72 obtained from the Cabot Corporation of Billerica, MA and about 50 percent Teflon, grade "TFE – 30", obtained from the aforesaid E. I. DuPont Company.

 The cell anode and cathode flow fields were porous and defined within anode and cathode water transport plates. The water transport plates were
15 porous graphite having a mean pore size of approximately 2 - 3 microns and a porosity of 35% - 40%. The plates were made wettable by treating them with tin oxide in a procedure described in U.S. Patent 5,840,414 owned by the assignee of all rights in the present invention. The cell had an active area of about 0.4 square feet, a porosity of 35% - 40%.

20 Alternatively, a fuel cell assembly 11 having antifreeze coolant channels formed in only one of the anode and cathode water transfer plates, 60 and 64 respectively, is also contemplated and may be employed without departing from the broader aspects of the present invention.

 While a proton exchange membrane, noble metal catalyst and carbon
25 fiber paper having a Teflon® coating have been described, the present invention is not limited in this regard as other membranes and substrate materials may be alternatively utilized, providing they allow for the necessary flow of reactant and by-product molecules and ions. Likewise, fuel cells having a non-solid acid based electrolyte or other fuel cell configurations,
30 such as are disclosed in commonly assigned U.S. Patents No. 4,769,297, issued to Reiser et al. and No. 5,503,944, issued to Meyer et al., may also be employed without departing from the broader aspects of the present invention.

With reference once again to Fig. 1, the present invention is directed towards a coolant treatment system for use with a fuel cell assembly **11** which also incorporates a direct antifreeze coolant solution. The coolant channels **78/80** of the fuel cell assembly **11** serve to address two main concerns of an operating fuel cell assembly: the water management of a fuel cell assembly, as well as the thermal management of a fuel cell assembly. In a PEM fuel cell assembly, for example the fuel cell assembly **11** as shown in Fig. 1, the PEM **52** must be sufficiently hydrated for the fuel cell assembly **11** to operate and continue to facilitate the migration of ions across the PEM **52**. One manner in which the PEM **52** remains hydrated during operation of the fuel cell assembly **11** is by humidifying either, or both of, the inputted fuel and oxidant streams traveling within the fuel and oxidant channels **72** and **76**, respectively.

In operation, it is desired that pure hydrogen be utilized as the fuel supply for the fuel cell assembly **11** shown in Fig. 1, but such pure hydrogen is often expensive to obtain and store. Other hydrocarbons such as methane, natural gas and gasoline are therefore utilized as a fuel, but only after these hydrocarbons have undergone a known reformation process to convert the hydrocarbons to a hydrogen rich fuel having a minimal amount of impurities within the fuel supply.

Reformed hydrocarbon fuels, however, typically contain quantities of ammonia, NH_3 , and hydrogen, H_2 , as well as significant quantities of carbon dioxide, CO_2 . The NH_3 and CO_2 gases dissolve and dissociate into the water which may be provided to, and created within, the fuel cell assembly. The gases react with the water and form ionic reaction by-products. In addition, water within the fuel cell assembly **11** containing concentrations of ammonia even as small as 2 parts per million (ppm) can act to displace protons in the PEM **52**, thereby reducing the conductivity of the PEM **52** and thus, the efficiency of the fuel cell assembly as a whole. Dissolved gases within the water may also result in gas bubbles in the coolant flow field of the fuel cell assembly **11** which may cause drying of the anode and cathode water

transfer plates, **60** and **64** respectively, thereby resulting in mixing of the reactants.

It would therefore be very beneficial to equip a fuel cell assembly **11** with a coolant treatment system that can remove water contamination within
5 the fuel cell assembly **11**, and thereby prevents damage to the fuel cell assembly **11** due to the resultant effects of such contamination, as well as providing the fuel cell assembly **11** with a direct antifreeze coolant supply to protect against potentially hazardous temperature extremes.

It is a major aspect of the present invention, therefore, to provide such
10 a coolant treatment system for use with a fuel cell stack **11**. Fig. 2 illustrates one such coolant treatment system **100** according to an embodiment of the present invention. Only a single fuel cell assembly **11** is shown in Fig. 2, including coolant channels **78/80**, fuel flow channels **72** and oxidant flow channels **76**, for simplicity; however, it will be readily apparent that the coolant
15 treatment system **100** is equally applicable to either a single fuel cell assembly **11** or a fuel cell stack comprised of a plurality of electrically coupled fuel cell assemblies.

Still in reference to Fig. 2, a fuel cell assembly **11** receives reactant fuel from a fuel supply component **120**, typically from a fuel processing
20 system producing a hydrogen rich fuel. The reactant fuel circulates throughout the fuel cell assembly **11** and exits through a fuel exit conduit **122**. The fuel cell assembly **11** is further equipped with an integrated oxidant supply and a direct antifreeze coolant loop **144**.

The direct antifreeze coolant loop **144** includes a coolant feed conduit
25 **161** which directs an antifreeze solution to the coolant channels, **78** and **80**, of the fuel cell assembly **11**. In circulating through the coolant channels **78** and **80**, the antifreeze solution absorbs and carries away a portion of the heat generated by the fuel cell assembly **11**. In addition, the antifreeze solution serves to carry away a substantial amount of the water by-product which has
30 been formed within the fuel cell assembly **11** during operation. The by-product water, as well as any NH_3 and CO_2 , dissolves into the antifreeze

solution. Therefore, the by-product water is typically contaminated with dissolved and dissociated gases and, if present, suspended solids.

Upon exhaust from the fuel cell assembly **11**, a coolant discharge conduit **160** carries exhausted antifreeze solution from the fuel cell assembly **11** to a coolant pump **138** which, in conjunction with a pressure control valve **148**, maintains a predetermined flow rate and pressure of the circulated antifreeze solution. As is well known, the pressure control valve **148** may be set manually, automatically, or, for example, may be electro-mechanically adjusted based upon a reference pressure of the reactant oxidant stream within the fuel cell assembly **11** to thereby restrict flow through the pressure control valve **148** so that the antifreeze coolant stream circulating through the coolant channels, **78** and **80**, is at a pressure lower than the pressure of the oxidant stream within the oxidant flow channels **76**. Additional pressure control means may include any known mechanism that can reduce pressure of a liquid stream below a reference pressure of a gaseous stream. One such pressure control means is disclosed in commonly-assigned U.S. Patent No. 5,700,595, issued to Reiser.

Returning to Fig. 2, a portion of the exhausted antifreeze solution is fed to a coolant heat exchanger **139**, comprising a fan apparatus or the like, which is operable to remove a portion of the absorbed heat from the circulated antifreeze solution. In total, the coolant feed conduit **161**, the coolant channels **78** and **80**, the coolant heat exchanger **139**, the pressure control valve **148** and the coolant discharge conduit **160** comprise elements of the coolant loop **144** for regulating the operating temperature of the fuel cell assembly **11**.

The coolant treatment system **100** further provides for the humidification of an inputted oxidant stream by utilizing the water in the coolant supplied by a reclamation conduit **163** for delivery to a degasifier portion **151** of a degasifying apparatus **145**. The degasifying apparatus **145** of the present invention is utilized to partially cleanse the coolant and houses a reservoir portion **149** for accumulating such purified coolant. The reservoir

portion **149** also accommodates changes in coolant fluid volume due to changes in operating conditions.

In the embodiment shown in Fig. 2, an oxidant source apparatus **147**, typically a variable speed blower-pump or the like, is the primary source of reactant oxidant for the oxidant flow channels **76** of fuel cell assembly **11**.
5 The oxidant source apparatus **147** does not, however, provide the fuel cell assembly **11** with a supply of oxidant directly, but rather first provides the degasifying apparatus **145** with a supply of oxygen-rich oxidant, typically in the form of air. An oxidant feed conduit **162** serves as a path for feeding a
10 reactant oxidant treated by the degasifying apparatus **145** to the oxidant flow channels **76** of the fuel cell assembly **11**.

As is further illustrated in Fig. 2, an oxidant control valve **165** may alternatively be arranged to feed only a fraction of the generated reactant oxidant, typically approximately 3% - 7% of the total oxidant flow, to the
15 degasifier portion **151**, while the balance is fed directly to the oxidant flow channels **76**. An oxidant flow of approximately 3% - 7% is typically sufficient to reduce the level of dissolved gases in the coolant to an acceptable level, however the required oxidant flow may need to be correspondingly higher if contamination of the water is excessive.

20 In operation, the coolant treatment system **100** of Fig. 2 delivers the contaminated by-product water and the antifreeze solution from the coolant pump **138**, through a reclamation conduit **163**, to the degasifying apparatus **145**. The antifreeze solution passes through the degasifier portion **151** in a counter-current manner to the oxidant air which is introduced into the
25 degasifying apparatus **145** below the degasifier portion **151** through the action of the oxidant source apparatus **147**. Mass transfer in the degasifier portion **151** results in a significant fraction of the dissolved gases in the antifreeze solution diffusing into the oxidant stream, thus stripping most of the dissolved gases from the antifreeze solution. This results in a purified coolant
30 with an acceptable conductivity and dissolved-gas content. In addition, the oxidant air will become humidified by the counter flowing antifreeze solution, in a manner important to the operation of the fuel cell assembly **11**, as

discussed previously. The humidified oxidant is transported from the degasifying apparatus **145** by an oxidant feed conduit **162**, to be subsequently supplied to the oxidant flow channels **76** of the fuel cell assembly **11**. An exhausted oxidant stream, which has circulated through the oxidant flow channels **76**, is carried by an oxidant exhaust conduit **164** to be forwarded to an unillustrated water recovery system and/or a fuel processing system.

The degasifying apparatus **145** may be any known mass transfer device capable of effecting mass transfer between a liquid stream and a gas stream. Examples of such mass transfer devices are packed beds, wetted films, spray towers, or the like.

The coolant treatment system **100** shown in Fig. 2, illustrates other water purification devices as well. A demineralizer **140** is configured to accept a portion of the purified antifreeze solution, directed to the fuel cell assembly **11** from the reservoir portion **149**, in order to assist in the reduction of suspended solids and dissolved gasses in the coolant. Moreover, an unillustrated secondary heat exchanger may be located upstream of the demineralizer **140** so as to provide the by-product water to the demineralizer **140** at a temperature appropriate for proper functioning of the demineralizer **140**, approximately 60°C (140°F) or less.

By arranging the demineralizer **140** downstream from the degasifying apparatus **145**, the coolant treatment system **100** further reduces the load upon the demineralizer **140** through the reduction of ionizable dissolved gasses such as CO₂ which correspondingly increases the life of the demineralizer **140**. Likewise, by assisting the degasifying apparatus **145** in the reduction of the contaminants present in the antifreeze solution, the demineralizer **140** advantageously acts to prolong the life of the degasifying apparatus **145** as well.

It should be readily apparent that the trim valves shown in Fig. 2 are controlled so as to maintain a balance between the heat generated in the fuel cell assembly **11** and the heat rejected to the environment. The antifreeze solution flow rates and the temperature of the antifreeze solution at various

locations within the coolant treatment system **100** are controlled to provide efficient operation of the fuel cell assembly **11** and the coolant treatment system **100**.

The coolant treatment system of the present invention significantly
5 reduces the amount of dissolved ammonia, carbon dioxide and hydrogen
within the coolant of the fuel cell assembly **11**. It is therefore a major aspect
of the present invention that the oxidant processed by the degasifying
apparatus **145** enables removal of the dissolved gases contaminating
antifreeze solution, and moreover, that the oxidant supply subsequently
10 provided to the oxidant flow channels **76** will have been previously humidified
by the degasifying apparatus **145**. In this manner, two considerations
important to the operation of the fuel cell assembly **11** are accomplished
utilizing a single integrated treatment system.

The coolant treatment system **100** additionally provides for another
15 important aspect of the present invention by utilizing a direct antifreeze
solution as the coolant for the fuel cell assembly **11**. By doing so, the fuel cell
assembly **11** is protected against freezing temperature extremes without the
added weight and volume inherent in those systems utilizing separate cooler
plates which are sealed from fluid communication with the body of a fuel cell
20 assembly or stack.

While Fig. 2 illustrates one possible configuration of an integrated
coolant treatment system utilizing a direct antifreeze solution, it should be
readily apparent that other, alternative configurations are also envisioned by
the present invention. Fig. 3 illustrates one such alternative embodiment of a
25 coolant treatment system of the present invention, generally indicated by the
numeral **200**.

As depicted in Fig. 3, only a single fuel cell assembly **11** is shown
incorporated in the coolant treatment system **200**, including coolant channels
78/80, fuel flow channels **72** and oxidant flow channels **76**, for simplicity;
30 however, it will be readily apparent that the coolant treatment system **200** is
equally applicable to either a single fuel cell assembly **11** or a fuel cell stack
comprised of a plurality of electrically coupled fuel cell assemblies.

Still in reference to Fig. 3, a fuel cell assembly **11** receives reactant fuel from fuel supply component **220**, typically as the result of the output from a fuel processing system producing a hydrogen rich fuel. The reactant fuel circulates throughout the fuel cell assembly **11** and exits through a fuel exit conduit **222**. The fuel cell assembly **11** is further equipped with an integrated oxidant supply and a direct antifreeze coolant loop **244**.

The direct antifreeze coolant loop **244** includes a coolant feed conduit **261** which directs an antifreeze solution to the coolant channels, **78** and **80**, of the fuel cell assembly **11**. In circulating through the coolant channels **78** and **80**, the antifreeze solution absorbs and carries away a portion of the heat generated by the fuel cell assembly **11**. In addition, the antifreeze solution serves to carrying away a substantial amount of the water by-product which has been formed within the fuel cell assembly **11** during operation. The by-product water, as well as any NH_3 and CO_2 , dissolves into the antifreeze solution. Therefore, the by-product water is typically contaminated with dissolved and dissociated gases and, if present, suspended solids, as discussed previously.

Upon discharge from the fuel cell assembly **11**, a coolant discharge conduit **260** carries exhausted antifreeze solution from the fuel cell assembly **11** to a coolant pump **238** which, in conjunction with a pressure control valve **248**, maintains a predetermined flow rate and pressure of the circulated antifreeze solution. As was discussed previously in conjunction with Fig. 2, the pressure control valve **248** may be set manually, automatically, or, for example, may be electro-mechanically adjusted based upon a reference pressure of the reactant oxidant stream within the fuel cell assembly **11** to thereby restrict flow through the pressure control valve **248** so that the antifreeze coolant stream circulating through the coolant loop **244** is at a pressure lower than the pressure of the oxidant stream within the oxidant flow channels **76**.

Returning to Fig. 3, a portion of the antifreeze solution exhausted from the fuel cell assembly **11** is fed to a coolant heat exchanger **239**, comprising a fan apparatus or the like, which is operable to remove a portion of the

absorbed heat from the circulated antifreeze solution. In total, the coolant feed conduit **260**, the coolant channels **78** and **80**, the coolant heat exchanger **239** and the pressure control valve **248** operate as the coolant loop **244** for regulating the operating temperature of the fuel cell assembly **11**.

5 The coolant treatment system **200** further provides for the humidification of an oxidant stream by utilizing the water present in the coolant supplied by a reclamation conduit **263** for delivery to a degasifier portion **251** of a degasifying apparatus **245**. The degasifying apparatus **245** of the present invention is utilized to partially cleanse the coolant and houses
10 a reservoir portion **249** for accumulating such purified coolant. The reservoir portion **249** is situated downstream of the reclamation conduit **263** for accepting the antifreeze solution, which contains contaminated by-product water that has been carried from the fuel cell assembly **11** along with the circulated antifreeze solution. The reservoir portion **249** also accommodates
15 changes in coolant fluid volume due to changes in operating conditions.

 The reservoir portion **249** is situated downstream of a reclamation conduit **263** for accepting a measured amount of the contaminated antifreeze solution that has been carried from the fuel cell assembly **11**. The reservoir portion **249** also accommodates changes in coolant fluid volume due to
20 changes in operating conditions.

 An oxidant source apparatus **247**, typically a variable speed blower-pump or the like, is the primary source of reactant oxidant for the oxidant flow channels **76** of fuel cell assembly **11**. In contrast to the embodiment disclosed in Fig. 2, the oxidant source apparatus **247** supplies the fuel cell
25 assembly **11** with a supply of oxygen-rich oxidant directly by way of an oxidant supply conduit **266**. An oxidant control valve **265** is utilized to divert a portion of the exhausted oxidant, typically approximately 3% - 7% of the total oxidant flow, to the degassifier portion **251**, while the balance of the exhausted oxidant is fed to either the water recovery system or the fuel
30 processing system (not shown). The unillustrated water recovery system may include a condensing heat exchanger or other appropriate means for recovering water from the exhausted oxidant stream.

In operation, the coolant treatment system **200** of Fig. 3 delivers the contaminated antifreeze solution through the reclamation conduit **263** to the degasifying apparatus **245**. The coolant passes through the degasifier portion **251** in a counter-current manner to the oxidant air which is introduced, via an oxidant input conduit **268**, into the degasifying apparatus **245** below the degasifier portion **251**. Mass transfer in the degasifier portion **251** results in a significant fraction of the dissolved gases in the coolant diffusing into the oxidant stream, thus stripping most of the dissolved gases from the water. This process results in a purified coolant with an acceptable conductivity and dissolved-gas content, while the now-humidified oxidant stream is fed back to the oxidant source apparatus **247** for subsequent supply to the fuel cell assembly **11**.

The degasifying apparatus **245** may be any known mass transfer device capable of effecting mass transfer between a liquid stream and a gas stream. Examples of such mass transfer devices are packed beds, wetted films, spray towers, or the like.

The coolant treatment system **200** shown in Fig. 3 illustrates other coolant purification devices as well. A demineralizer **240** is supplied through a trim conduit **262** with a portion of the purified coolant from the reservoir portion **249** according to the action of a water trim valve **256**, for the reduction of suspended and dissolved gasses and, if present, suspended solids, in the purified water.

By arranging the demineralizer **240** downstream from the degasifying apparatus **245**, the coolant treatment system **200** further reduces the load upon the demineralizer **240** through the reduction of ionizable dissolved gasses such as CO₂ which correspondingly increases the life of the demineralizer **240**. Likewise, by assisting the degasifying apparatus **245** in the reduction of the contaminants present in the antifreeze solution, the demineralizer **240** advantageously acts to prolong the life of the degasifying apparatus **245** as well..

It should be readily apparent that the trim valves shown in Fig. 3 are controlled so as to maintain a balance between the heat generated in the fuel

cell assembly **11** and the heat rejected to the environment. The antifreeze solution flow rates and the antifreeze solution temperatures at various locations within the coolant treatment system **200** are controlled to provide efficient operation of the fuel cell assembly **11** and the coolant treatment
5 system **200**.

It is a major aspects of the preferred embodiment of Fig. 3 that at least a portion of the inputted oxidant stream be subjected to humidification process each time before being presented to the fuel cell assembly. In addition, since all of the coolant fed to the demineralizer **240** will already have
10 been passed through the degasifier **245**, the configuration of Fig. 3 provides for improved cleansing of any dissolved gases from the water, and therefore improved fuel cell operation and longevity. Moreover, the demineralizer **240** will also enjoy a longer usable life span due to the reduction in contaminants the demineralizer **240** must remove.

15 The coolant treatment system of Fig. 3 significantly reduces the amount of ammonia, carbon dioxide and hydrogen within the coolant stream of the fuel cell assembly **11**. Consequently, according to a major aspect of the present invention, buildup of these gases within the fuel cell assembly **11** can be reduced, as well as extending the time between maintenance on the
20 demineralization apparatus **240**.

In accordance with an important aspect of the present invention, and similar to Fig. 2's disclosed embodiment, Fig. 3 depicts an integrated coolant treatment system utilizing a direct antifreeze solution. Such a configuration protects the fuel cell assembly **11** from freezing temperature extremes without
25 the added weight and volume inherent in those systems utilizing separate cooler plates which are sealed from fluid communication with the body of a fuel cell assembly or stack. Moreover, by equipping a fuel cell assembly or stack with a direct antifreeze solution, the start-up time for a cold or frozen fuel cell assembly or stack is correspondingly reduced.

30 As can be seen from the foregoing disclosure and figures in combination, a coolant treatment system according to the present invention is advantageously provided with a plurality of beneficial operating attributes,

including but not limited to: humidifying the inputted oxidant stream, maintaining the fuel cell assembly coolant system above its freezing point or quickly raising a cold or frozen fuel cell assembly above freezing, lessening the weight and volume of a temperature-protected fuel cell assembly or stack
5 and cleansing the coolant within the overall system to remove potentially harmful and debilitating contamination. All of these attributes contribute to the efficient operation of a fuel cell assembly and are especially beneficial to those applications, such as motor vehicle manufacturing, which demand high performance, reliability and low volume and weight.

10 While the invention had been described with reference to the preferred embodiments, it will be understood by those skilled in the art that various obvious changes may be made, and equivalents may be substituted for elements thereof, without departing from the essential scope of the present invention. Therefore, it is intended that the invention not be limited to the
15 particular embodiments disclosed, but that the invention includes all embodiments falling within the scope of the appended claims.

CLAIMS

1. A coolant treatment system for a fuel cell power plant having a plurality of electrochemical fuel cell assemblies in electrical connection with each other, said fuel cell assemblies each having an electrolyte, an anode, a cathode, each of said anode and said cathode are adapted to support anode and cathode water transport plates through which a fuel and an oxidant are fed to said anode and said cathode, respectively, one of said anode and cathode water transport plates being adapted to support a coolant channel through which an antifreeze solution is circulated, said system comprising:
- 5 an oxidant source for providing said fuel cell power plant with said oxidant;
- a coolant conduit through which said antifreeze solution is exhausted from said fuel cell power plant;
- a degasifying apparatus which accepts said oxidant and said antifreeze solution for subsequent interaction with one another thereby treating both said oxidant and said antifreeze solution by removing contaminants from said antifreeze solution and by humidifying said oxidant, said degasifying apparatus providing said fuel cell power plant with said humidified oxidant; and
- 15 wherein said antifreeze solution is in fluid communication with one of said anode and cathode water transport plates.
- 20

2. The coolant treatment system for a fuel cell power plant according to claim 1, wherein:
said degasifying apparatus further comprises :
an oxidant inlet for receiving said oxidant prior to said oxidant being fed
5 to said fuel cell power plant;
a degasifier portion to which said antifreeze solution and said oxidant are provided, said degasifier portion enabling said interaction of said antifreeze solution and said oxidant to thereby treat said antifreeze solution by removing dissolved gases from said antifreeze solution while humidifying
10 said oxidant; and
a reservoir portion for collecting said treated antifreeze solution.
3. The coolant treatment system for a fuel cell power plant according to claim 2, wherein:
said antifreeze solution comprises water and an organic antifreeze;
and
5 said dissolved gases comprise at least one of ammonia, carbon dioxide and hydrogen gases.
4. The coolant treatment system for a fuel cell power plant according to claim 2, wherein:
said antifreeze solution has a freezing point of approximately -29°C, a surface tension greater than 60 dynes per centimeter, is capable of being
5 oxidized by catalysts of said fuel cell power plant and has a partial pressure of less than 0.005mm of mercury at approximately 65°C.
5. The coolant treatment system for a fuel cell power plant according to claim 2, wherein:
said antifreeze solution is an alkanetriol antifreeze solution.

6. The coolant treatment system for a fuel cell power plant according to claim 5, wherein:

said alkanetriol antifreeze solution is selected from the group consisting of glycerol, butanetriol and pentanetriol.

7. The coolant treatment system for a fuel cell power plant according to claim 2, wherein:

said fuel cell assemblies each further include an anode catalyst layer adjacent one side of said electrolyte and a cathode catalyst layer adjacent

5 another side of said electrolyte;

said anode support is wetproofed and positioned between said anode water transport plate and said anode catalyst; and

said cathode support is wetproofed and positioned between said cathode water transport plate and said cathode catalyst.

8. The coolant treatment system for a fuel cell power plant according to claim 7, wherein:

said antifreeze solution comprises a non-volatile antifreeze which does not wet said anode support and said cathode support.

9. The coolant treatment system for a fuel cell power plant according to claim 7, wherein:

said coolant treatment system further comprises:

a coolant heat exchanger located along said coolant conduit for

5 removing heat from a selected portion of said antifreeze solution; and

a demineralization device for purifying a selected portion of said antifreeze solution at a point after said antifreeze solution has been treated by said degasifying apparatus.

10. A coolant treatment system for a fuel cell power plant having a plurality of electrochemical fuel cell assemblies in electrical connection with each other, said fuel cell assemblies each having an electrolyte, an anode, a cathode, each of said anode and said cathode are adapted to support anode and cathode water transport plates through which fuel and oxidant are fed to said anode and said cathode, respectively, one of said anode and cathode water transport plates being adapted to support a coolant channel through which an antifreeze solution is circulated, said system comprising:
- a coolant conduit through which said antifreeze solution is exhausted from said fuel cell power plant;
 - an oxidant source for providing said fuel cell power plant with said oxidant, said oxidant being exhausted from said fuel cell power plant after circulation therethrough;
 - a degasifying apparatus which accepts said antifreeze solution and a selected portion of said oxidant for subsequent interaction with one another thereby treating both said antifreeze solution by removing contaminants from said antifreeze solution and said oxidant by humidifying said oxidant, said degasifying apparatus providing said fuel cell power plant with said humidified oxidant; and
- wherein said antifreeze solution is in fluid communication with one of said anode and cathode water transport plates.

11. The coolant treatment system for a fuel cell power plant according to claim 10, wherein:

said degasifying apparatus further comprises :

an exhausted oxidant inlet for accepting said oxidant exhausted from

5 said fuel cell power plant;

a degasifier portion to which said antifreeze solution and said oxidant are provided, said degasifier portion enabling said interaction between said antifreeze solution and said oxidant to thereby treat said antifreeze solution by removing dissolved gases from said antifreeze solution; and

10 a reservoir portion for collecting said antifreeze solution treated by said degasifying apparatus.

12. The coolant treatment system for a fuel cell power plant according to claim 11, wherein:

said antifreeze solution comprises water and an organic antifreeze;

and

5 said dissolved gasses comprise at least one of ammonia, carbon dioxide and hydrogen gases.

13. The coolant treatment system for a fuel cell power plant according to claim 11, wherein:

said antifreeze solution has a freezing point of approximately -29°C, a surface tension greater than 60 dynes per centimeter, is capable of being

5 oxidized by catalysts of said fuel cell power plant and has a partial pressure of less than 0.005mm of mercury at approximately 65°C.

14. The coolant treatment system for a fuel cell power plant according to claim 11, wherein:

said antifreeze solution is an alkanetriol antifreeze solution.

15. The coolant treatment system for a fuel cell power plant according to claim 14, wherein:

said alkanetriol antifreeze solution is selected from the group consisting of glycerol, butanetriol and pentanetriol.

16. The coolant treatment system for a fuel cell power plant according to claim 11, wherein:

said fuel cell assemblies each further include an anode catalyst layer adjacent one side of said electrolyte and a cathode catalyst layer adjacent
5 another side of said electrolyte;

said anode support is wetproofed and positioned between said anode water transport plate and said anode catalyst; and

said cathode support is wetproofed and positioned between said cathode water transport plate and said cathode catalyst.

17. The coolant treatment system for a fuel cell power plant according to claim 16, wherein:

said antifreeze solution comprises a non-volatile antifreeze which does not wet said anode support and said cathode support.

18. The coolant treatment system for a fuel cell power plant according to claim 16, wherein:

said coolant treatment system further comprises:

a coolant heat exchanger located along said coolant conduit for

5 removing heat from a selected portion of said antifreeze solution; and

a demineralization device for purifying a selected portion of said antifreeze solution at a point after said antifreeze solution has been treated by said degasifying apparatus.

19. A method of providing a coolant treatment system to a fuel cell power plant having a plurality of electrochemical fuel cell assemblies in electrical connection with each other, said fuel cell assemblies each having an electrolyte, an anode, a cathode, each of said anode and said cathode are
5 adapted to support anode and cathode water transport plates through which fuel and oxidant are circulated to said anode and said cathode, respectively, one of said anode and cathode water transport plates being adapted to support a coolant channel through which an antifreeze solution is circulated, said method comprising the steps of:

10 adapting said coolant channels so as to be in fluid communication with said anode and said cathode water transport plates;

exhausting said antifreeze solution from said fuel cell power plant;

providing an oxidant supply; and

providing a degasifying apparatus with said exhausted antifreeze

15 solution and said oxidant; and

operating said degasifying apparatus so as to remove contaminants from said antifreeze solution.

20. The method of providing a coolant treatment system to a fuel cell power plant according to claim 19, said method further comprising the steps of:

- directing said oxidant to said degasifying apparatus prior to said fuel
- 5 cell power plant being provided with said oxidant;
- providing a degasifier portion of said degasifying apparatus with said oxidant and said antifreeze solution to thereby treat said antifreeze solution by removing dissolved gases from said antifreeze solution while humidifying said oxidant; and
- 10 arranging a demineralization device downstream of said degasifying apparatus.

21. The method of providing a coolant treatment system to a fuel cell power plant according to claim 19, said method further comprising the steps of:

- exhausting oxidant from said fuel cell power plant;
- 5 directing a selected portion of said oxidant exhausted from said fuel cell power plant to said degasifying apparatus;
- providing a degasifier portion of said degasifying apparatus with said selected portion of said exhausted oxidant and said antifreeze solution to thereby treat said antifreeze solution by removing dissolved gases from said
- 10 antifreeze solution while humidifying said selected portion of said oxidant; and
- arranging a demineralization device downstream of said degasifying apparatus for purification of a selected portion of said antifreeze solution.

1/3

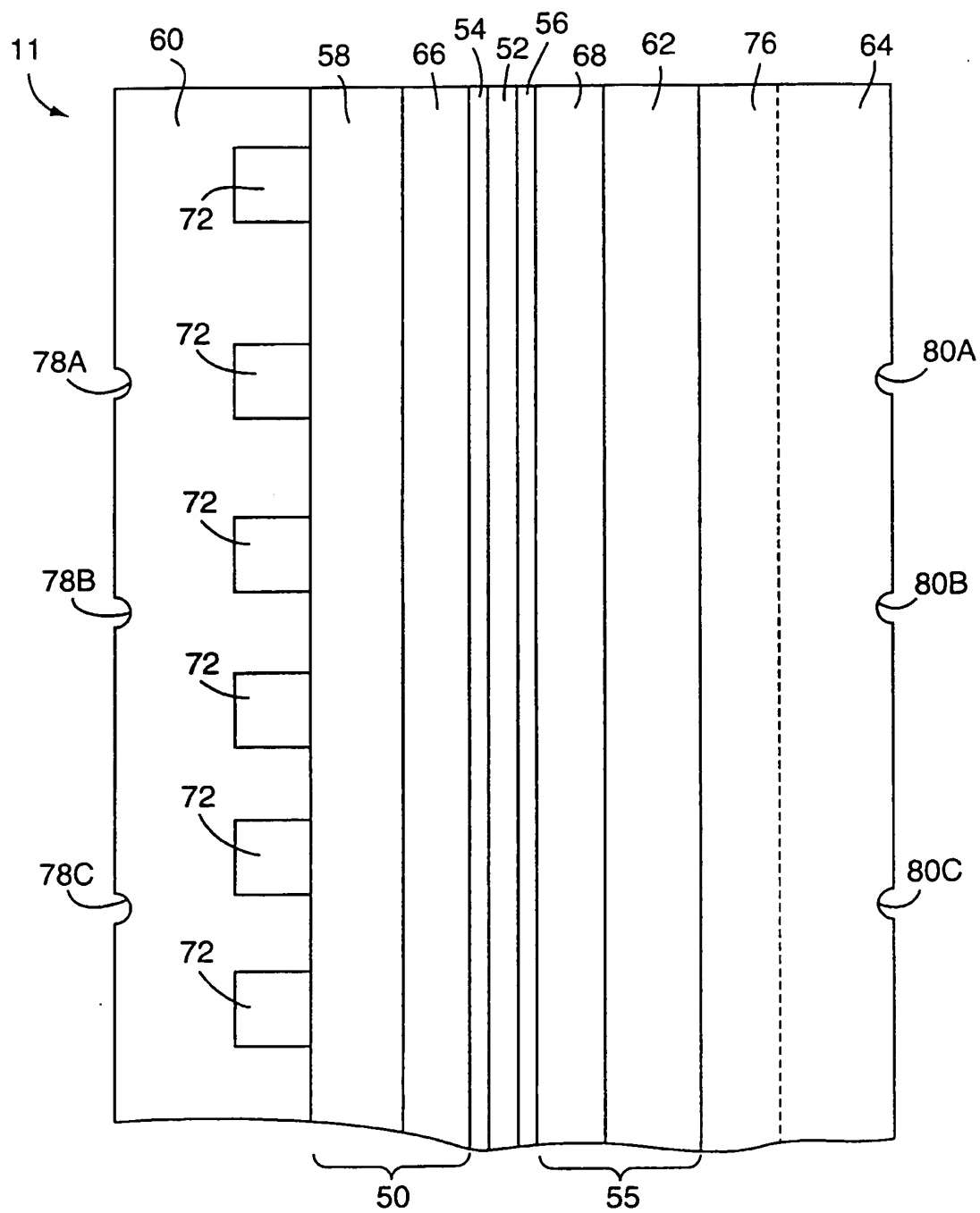


FIG. 1

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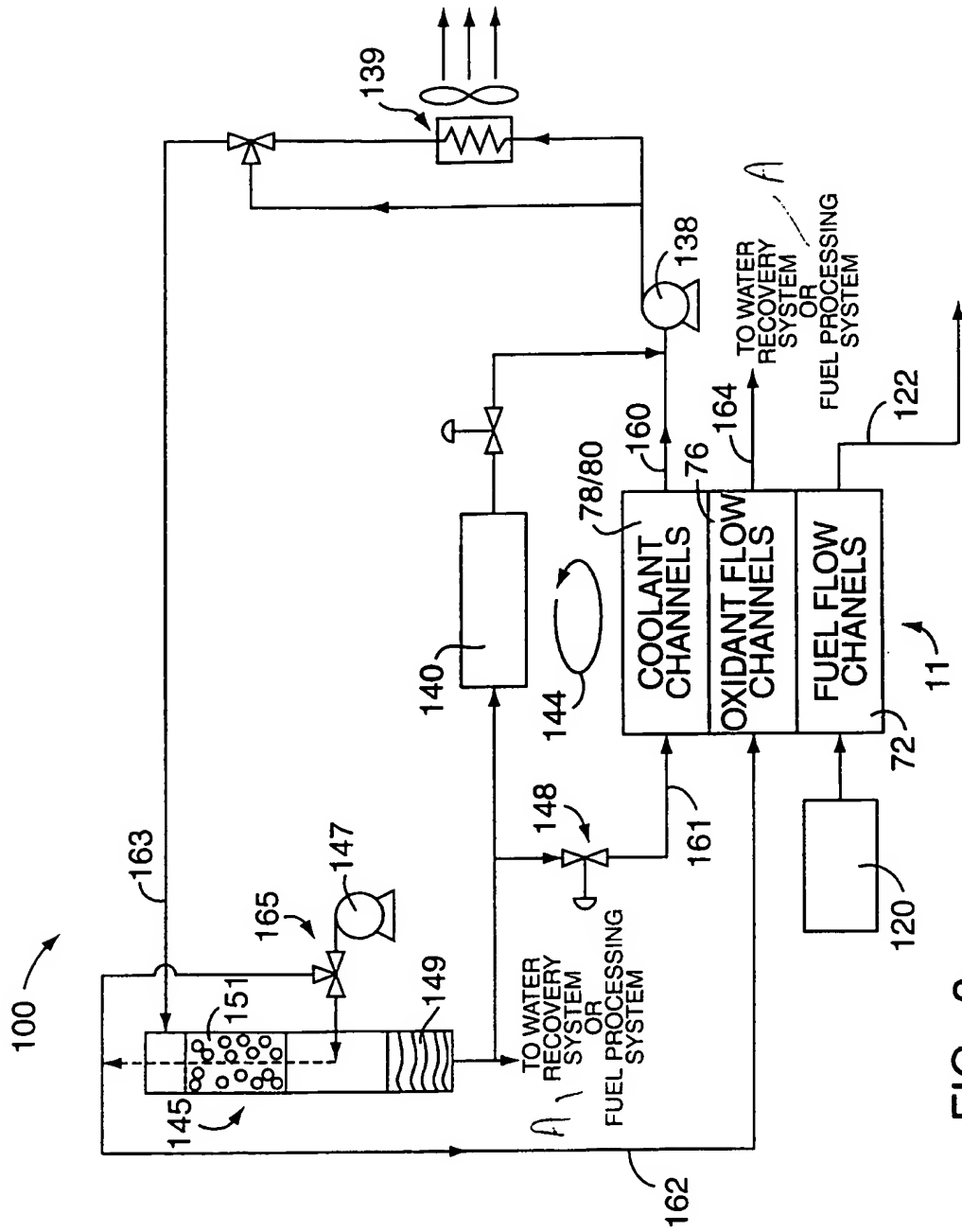


FIG. 2

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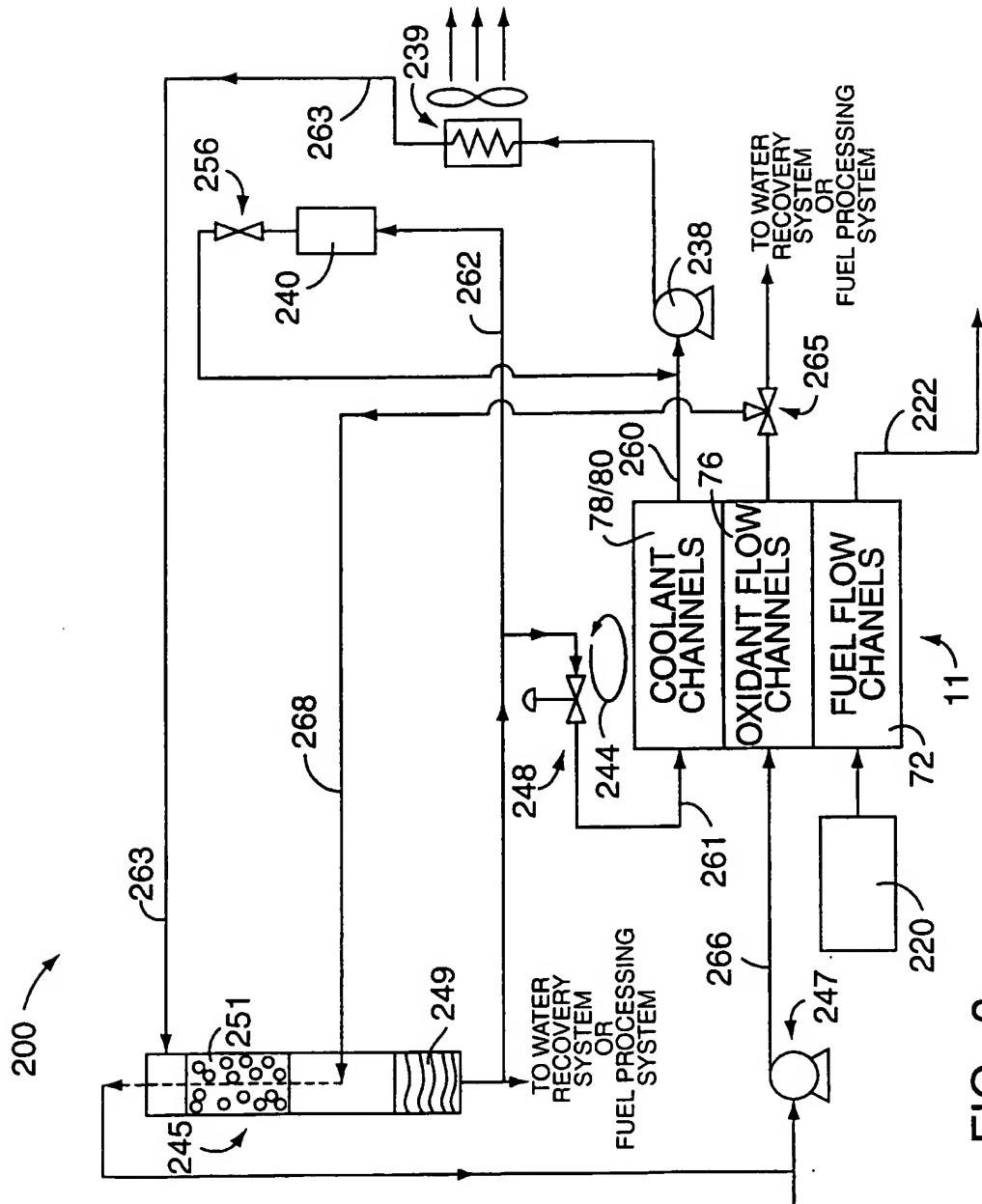



FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/34355

A. CLASSIFICATION OF SUBJECT MATTER IPC(7) :H01M 8/04 US CL :429/13, 26 According to International Patent Classification (IPC) or to both national classification and IPC																				
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) U.S. : 429/13, 17, 26, 34 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) Please See Extra Sheet.																				
C. DOCUMENTS CONSIDERED TO BE RELEVANT																				
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.																		
A	US 3,801,372 A (SHAW) 02 April 1974, col. 2, lines 11-19.	1-21																		
A	US 4,835,072 A (GRASSO et al) 30 May 1989, col. 5, lines 46-65.	1-21																		
A	US 4,855,192 A (GRASSO) 08 August 1989, col. 2, lines 42-54.	1-21																		
A	US 5,605,770 A (ANDREOLI et al) 25 February 1997, col. 5, lines 34-39.	1-21																		
A	US 5,503,944 A (MEYER et al) 02 April 1996, col. 6, lines 49-64.	1-21																		
A, P	US 6,013,385 A (DUBOSE) 11 January 2000, col. 3, lines 56-60.	1-21																		
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.																				
<table border="0"> <tr> <td>* Special categories of cited documents:</td> <td>*T*</td> <td>later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</td> </tr> <tr> <td>*A* document defining the general state of the art which is not considered to be of particular relevance</td> <td>*X*</td> <td>document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</td> </tr> <tr> <td>*E* earlier document published on or after the international filing date</td> <td>*Y*</td> <td>document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</td> </tr> <tr> <td>*L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</td> <td>*Z*</td> <td>document member of the same patent family</td> </tr> <tr> <td>*O* document referring to an oral disclosure, use, exhibition or other means</td> <td></td> <td></td> </tr> <tr> <td>*P* document published prior to the international filing date but later than the priority date claimed</td> <td></td> <td></td> </tr> </table>			* Special categories of cited documents:	*T*	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention	*A* document defining the general state of the art which is not considered to be of particular relevance	*X*	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone	*E* earlier document published on or after the international filing date	*Y*	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art	*L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*Z*	document member of the same patent family	*O* document referring to an oral disclosure, use, exhibition or other means			*P* document published prior to the international filing date but later than the priority date claimed		
* Special categories of cited documents:	*T*	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention																		
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Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230		Authorized officer STEPHEN J. KALAFUT Telephone No. (703) 308-0661 Jean Proctor  Paralegal Specialist																		

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US00/34355

B. FIELDS SEARCHED

Electronic data bases consulted (Name of data base and where practicable terms used):

EAST, WEST

search terms: fuel ajd cell, degasif\$, antifreeze, glycol, alkanetriol

(\$ is a truncation symbol)